

# **ELECTRICAL SIGNAL FILTER WITH SOLDERLESS GROUND CONNECTION**

## **CROSS-REFERENCE TO RELATED APPLICATION**

This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/438,742, filed on January 8, 2003, the entirety of which is incorporated herein by reference.

## **FIELD OF THE INVENTION**

[0001] The present invention relates to an electrical signal filter, such as those used in the CATV industry. More particularly, the present invention relates an electrical signal filter having at least one ground post configured to provide electrical contact between the filter housing and a filter component, such as a circuit board, and to enable solderless assembly of the filter housing and components.

## **BACKGROUND OF THE INVENTION**

[0002] Various types of electrical signal filters are used in the CATV industry for controlling, on a frequency basis, the propagation of signals through a cable line. In order to reduce production costs and increase manufacturing efficiency, constant strides have been made toward producing electrical signal filters that can be easily assembled by eliminating more costly manufacturing steps, such as precision soldering. Moreover, in an effort to reduce the labor intensive nature of the manufacturing process, focus has also shifted toward producing electrical signal filters using automated manufacturing processes, such as Z-axis manufacturing techniques.

[0003] Examples of electrical signal filters that can be assembled, at least in part, using automated Z-axis manufacturing are disclosed in U.S. Patent No. 6,429,754, issued August 6, 2002, U.S. Patent Application Serial No. 10/187,455, filed July 1, 2002, and U.S. Patent Application Serial No. 10/329,055, filed December 24, 2002 and now allowed, each assigned to Eagle Comtronics, Inc., the entireties of which are incorporated herein by reference.

[0004] The '455 Application and the '055 Application describe a split filter housing that can be vertically assembled using Z-axis assembly methods. The electrical signal filter includes an elongate lower filter housing member and an elongate upper filter housing member that abuts the lower filter housing member at a junction between the lower side surfaces of the upper filter housing member and the upper side surfaces of the lower filter housing member to define an internal filter cavity. Substantially cylindrical (i.e., round in cross-section) ground posts extend upwardly from the inner surface of the lower filter housing member in a direction substantially perpendicular to the longitudinal direction in which the lower and upper filter housing members each extend (e.g., the axial direction of the filter housing members). A circuit board positioned within the filter cavity includes ground holes that are through-plated with a conductive plating material.

[0005] The circuit board is placed within the lower filter housing member in the Z-axis manufacturing direction such that ground pins extending from the uppermost end of the ground posts pass through corresponding ground holes and extend above the upper surface of the circuit board. Once the circuit board is properly positioned on the ground posts, the tip portion of ground pin is peened over to form a solderless mechanical and electrical contact between the ground post and the plated ground hole in the circuit board.

In this case, the ground pin must be malleable enough to form a good mechanical and electrical contact with the upper surface of the plating after peening.

**[0006]** As the '455 and the '055 Applications describe, the ground pins can also include a recess extending a distance vertically into the ground pins to a position slightly below the upper surface of circuit board to insure that the peened tip portion of the ground pins make good mechanical and electrical contact with the top of the plating material extending out of the ground holes in the circuit board. The recesses in the ground pins assist in the mechanical deformation of the tip portion of the ground pins by allowing the ground pins to break at certain points, depending on the particular shapes of the ground pins and recesses, so that segments of the ground pins will be pressed outwardly and downwardly against the top of the plated ground hole during the peening operation. The recesses in the ground pins can be formed into a variety of different shapes, such as a cross, a Y-shape or an X-shape, to assist deformation during peening and achieve the desired mechanical and electrical connection between the top of the plated ground hole and the deformed (peened) end of the ground pin.

**[0007]** Although the split filter housing described above represents a step in a direction toward realizing automated Z-axis assembly and solderless manufacturing, room for improvement remains. That is, it would be desirable to provide an electrical signal filter that can be assembled using automated Z-axis manufacturing techniques and that further eliminates the need for peening the ground pins to make the solderless connection with the circuit board.

## **SUMMARY OF THE INVENTION**

**[0008]** It is an object of the present invention to provide an electrical signal filter that can be assembled using Z-axis manufacturing techniques and without any soldering steps.

Accordingly, one embodiment of the present invention provides an electrical signal filter including a first filter housing member extending along a longitudinal direction from a first end thereof to an opposed second end thereof, and having an inner surface terminating at first and second side surfaces that extend from the first end to the second end, and a second filter housing member extending along the longitudinal direction from a first end thereof to an opposed second end thereof, and having an inner surface terminating at first and second side surfaces that extend from the first end to the second end. The second filter housing member abuts the first filter housing member at a junction between the first and second side surfaces of the second filter housing member and the first and second side surfaces of the first filter housing member, respectively, to thereby define an internal filter cavity.

**[0009]** A circuit board is also provided, positioned within the filter cavity, and having at least one through-hole passing from a first surface thereof to an opposed second surface thereof. Each through-hole is plated with a conductive substance from the first surface of the circuit board to the second surface of the circuit board to form at least one plated ground hole passing through the circuit board from the first surface to the second surface thereof. Further, at least one ground post is provided, extending away from the inner surface of the first filter housing member in a direction substantially perpendicular to the longitudinal direction. Each ground post has at least a first portion with an outer dimension that is greater than an inner diameter of each respective plated ground hole in

the circuit board. The circuit board is positioned within the filter cavity such that at least the first portion of each ground post extends into a respective plated ground hole to achieve secure ground contact between the circuit board and the first filter housing member in a solderless manner.

**[0010]** Preferably, each ground post also includes a second portion adjacent a first end of the first portion and having an outer dimension that is greater than the outer dimension of the first portion. The second surface of the circuit board contacts the second portion, and at least part of the first portion extends into the plated ground hole.

**[0011]** It is also preferred that each ground post includes a third portion adjacent a second end of the first portion and having an outer dimension that is less than the outer dimension of the first portion, such that the third portion guides the plated ground hole in the circuit board onto the first portion of each ground post.

**[0012]** Preferably, at least the first portion of each ground post is polygonal, and more preferably, the polygonal portion has a square cross-sectional shape. Although the circuit board can be constructed of a material such as FR-4 (glass-epoxy), which offers a limited degree of flexibility, the size of the ground hole in the circuit board and the outer dimension (i.e., corner-to-corner diagonal dimension of the square) of the first portion of the ground post should be sufficiently dimensioned to prevent damaging the circuit board upon assembly.

**[0013]** It is also preferred that the outer peripheral edge of the through-hole in the circuit board is spaced from a side edge of the circuit board a distance substantially equal to at least one half of the thickness of the circuit board. It is further preferred that the sides of

the polygonal first portion of the ground post are arranged parallel to the sides of the circuit board.

**[0014]** Moreover, two ground posts are preferably provided, extending from opposite lateral sides of the inner surface of the first filter housing member and spaced a distance from one another in the longitudinal direction. At least one magnetic isolation shield member can also be provided, interposed between the two ground posts. The shield member includes a surface that is arranged at a height that is substantially the same as the height of the second portions of the ground posts to provide additional support for the circuit board.

**[0015]** The ground post is preferably integrally formed with the first filter housing member, and can be cast, for example, as a part of the first filter housing member.

**[0016]** According to another embodiment of the present invention, an electrical signal filter is provided, including a first filter housing member extending along a longitudinal direction from a first end thereof to an opposed second end thereof, and having an inner surface terminating at first and second side surfaces that extend from the first end to the second end, and a second filter housing member extending along the longitudinal direction from a first end thereof to an opposed second end thereof, and having an inner surface terminating at first and second side surfaces that extend from the first end to the second end. The second filter housing member is positioned to abut the first filter housing member at a junction between the first and second side surfaces of the second filter housing member and the first and second side surfaces of the first filter housing member, respectively, to thereby define an internal filter cavity.

**[0017]** A circuit board is provided, positioned within the filter cavity, and having at least one through-hole passing from a first surface thereof to an opposed second surface thereof. Each through-hole is plated with a conductive substance from the first surface of the circuit board to the second surface of the circuit board to form at least one plated ground hole passing through the circuit board from the first surface to the second surface thereof. At least one ground post is provided, extending away from the inner surface of the first filter housing member in a direction substantially perpendicular to the longitudinal direction. Each ground post has at least a first portion with an outer dimension that is greater than an inner diameter of the plated ground hole. At least one second post member is provided, extending from a first end thereof away from the inner surface of the second filter housing member toward an opposed terminal end thereof in a direction substantially perpendicular to the longitudinal direction. The circuit board is positioned within the filter cavity such that the second post member exerts a force upon the first surface of the circuit board such that at least the first portion of the ground post extends into the plated ground hole to achieve secure electrical grounding contact between the circuit board and the first filter housing member in a solderless manner.

**[0018]** Similar to the above first embodiment, each ground post preferably includes a second portion adjacent a first end of the first portion and having an outer dimension that is greater than the outer dimension of the first portion. The second surface of the circuit board contacts the second portion, and at least part of the first portion extends into the plated ground hole. It is also preferred that each ground post includes a third portion adjacent a second end of the first portion and having an outer dimension that is less than

the outer dimension of the first portion, such that the third portion guides the plated ground hole in the circuit board onto the first portion of each ground post.

**[0019]** Each second post member is preferably arranged to be substantially coaxial with a corresponding ground post. It is also preferred that the terminal ends of each second post member further comprises a recess having an inner dimension sufficient to receive the third portion of a corresponding ground post, preferably in a press-fit manner. Further, it is also preferred that the terminal ends of each second post member is spaced from the second portion of the ground post a distance substantially equal to the thickness of the circuit board.

**[0020]** According to another embodiment of the present invention, an electrical signal filter is provided, including a first filter housing member extending along a longitudinal direction from a first end thereof to an opposed second end thereof, and having an inner surface terminating at first and second side surfaces that extend from the first end to the second end, and a second filter housing member extending along the longitudinal direction from a first end thereof to an opposed second end thereof, and having an inner surface terminating at first and second side surfaces that extend from the first end to the second end. The second filter housing member abuts the first filter housing member at a junction between the first and second side surfaces of the second filter housing member and the first and second side surfaces of the first filter housing member, respectively, to thereby define an internal filter cavity.

**[0021]** A circuit board is also provided, positioned within the filter cavity. The circuit board includes at least one through-hole passing from a first surface thereof to an opposed second surface thereof, and at least a portion of the circuit board proximate the

through-hole is plated with a conductive substance to form a ground terminal. At least one ground post is provided, extending away from the inner surface of the first filter housing member in a direction substantially perpendicular to the longitudinal direction. Each ground post has at least a first portion having an outer dimension that is greater than an inner diameter of each one through-hole. The circuit board is positioned within the filter cavity such that the first portion of each ground post extends into the through-hole and contacts the ground terminal to achieve secure ground contact between the circuit board and the first filter housing member in a solderless manner.

**[0022]** Preferably, the first portion of the ground post further comprises a plurality of projected edges extending outwardly toward a second portion of the ground post. It is also preferred that the through-hole in the circuit board is not through-plated, and the ground terminal is preferably formed at least on the second surface of the circuit board, such that the plurality of projected edges contact, engage and indent the planar surface of the ground terminal to achieve a secure ground contact between the circuit board and the first filter housing member in a solderless manner. A ground terminal can also be formed on the first surface of the circuit board, as well.

**[0023]** Since the through-holes formed in the circuit board of this embodiment are not through-plated, solder does not tend to accumulate therein when subjected to wave soldering operations during the fabrication of the circuit board itself, prior to filter assembly. Accordingly, the expense associated with various methods for removing excess solder from plated ground holes of the circuit board (before the electrical signal filter can be assembled) is not incurred. Thus, another expensive step is eliminated, and a solderless ground connection is afforded by the present invention.

**[0024]** According to another embodiment of the present invention, at least one second post member extending from a first end thereof away from the inner surface of the second filter housing member toward an opposed terminal end thereof in a direction substantially perpendicular to said longitudinal direction is also provided in addition to the embodiment described immediately above. Preferably, each second post member is substantially coaxial with a respective ground post extending from the first filter housing member. It is also preferred that the terminal end of each second post member includes a recess having an inner dimension sufficient to receive a third portion of a respective ground post that extends toward the second filter housing member a distance beyond the first surface of the circuit board in a press-fit manner. The mechanical relationship between each ground post and second post member enables the secure assembly of the first and second filter housing members with the circuit board interposed therebetween. Thus, an additional soldering step is avoided and assembly of the first and second filter housing members can be accomplished using Z-axis manufacturing techniques.

**[0025]** It is also preferred that the terminal end of each second post member includes a plurality of projected portions extending therefrom and away from the second filter housing member. The plurality of projected portions contact, engage and indent the planar surface of a ground terminal provided on the first surface of the circuit board to achieve mechanical engagement with the circuit board and to provide secure ground contact between the circuit board, a respective ground post and the second filter housing member in a solderless manner.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

[0026] For a more complete understanding of the nature and objects of the present invention, reference should be made to the following detailed description of a preferred mode of practicing the invention, read in connection with the accompanying drawings, in which:

FIG. 1 is a cross-sectional end view of vertically opposed first and second filter housing members according to one embodiment of the present invention;

FIGS. 2A-2B are partial top and cross-sectional views of the relationship between the ground post and second post member shown in Fig. 1;

FIG. 3 is a cross-sectional view showing the relationship between the portions of the ground post and the plated ground hole in the circuit board according to one embodiment of the present invention;

FIG. 4 is a partial top view of the circuit board, the ground post and the plated ground hole shown in Fig.3;

FIG. 5 is a cross-sectional view showing the relationship between the portions of the ground post, the plated ground hole in the circuit board, the terminal portion of the second post member and the recess of the second post member according to one embodiment of the present invention;

FIG. 6 is a partial perspective view of a circuit board showing a preferred distance between adjacent edges of the circuit board and the peripheral edges of a through-hole formed therein;

FIG. 7 is an exploded view of a filter assembly according to one embodiment of the present invention;

FIG. 8 is a top view of a first filter housing member according to another embodiment of the present invention;

FIG. 9 is an end-view of the first filter housing member shown in Fig. 8 taken through line 9-9;

FIG. 10A is a cross-sectional view showing the relationship between the portions of the ground post, the ground terminal proximate the non-plated through-hole on the second surface of the circuit board, the terminal portion of the second post member, the ground terminal proximate the non-plated through-hole on the first surface of the circuit board and the recess of the second post member according to another embodiment of the present invention;

FIG. 10B is a cross-sectional view of the structure of Fig. 10A shown rotated about 45° with respect to a central axis of the ground post and the second post member;

FIG. 11A is a partial top view of the ground post and circuit board shown in Fig. 10A; and

FIG. 11B is a partial bottom view of the second post member and the circuit board shown in Fig. 10B.

## **DETAILED DESCRIPTION OF THE INVENTION**

[0027] Fig. 1 is a cross-sectional end view showing vertically opposed first and second filter housing members **1**, **20** according to one embodiment of the present invention. As shown, a ground post **12** is positioned proximate the right-hand side of Fig. 1 and extends in a substantially vertical direction (i.e., upward) from an inner surface **1A** of the first filter housing member **1**. The ground post **12** includes a second portion **14** proximate the

inner surface **1A** of the first filter housing member **1**, a vertically adjacent first portion **13** and a third portion **15** vertically adjacent the first portion **13**.

**[0028]** The first filter housing member **1** also includes a shield member **11**, to provide magnetic isolation between filter components within the filter housing assembly, for example. The shield member **11** includes a first portion **11A** and adjacent stepped portions **11B** and **11C**. Stepped portion **11C** can be dimensioned to function as a spark-gap, as described in U.S. Patent Application Serial No. 09/654,593, filed September 1, 2000, now allowed, the entirety of which is incorporated herein by reference. Stepped portion **11B** functions to support part of a circuit board **30** (shown in Fig. 2B). It is preferred that the uppermost distance (e.g., the height) of the surface **11B** of the shield member **11** from the inner surface **1A** of the first filter housing member **1** is substantially the same as the height of the second portion **14** of the ground post **12**.

**[0029]** As shown in Fig. 2B, the circuit board **30** includes a first (i.e., upper) surface **31**, a second (i.e., lower) surface **32**, and a through-hole **33** passing from the first surface **31** to the second surface **32**. A portion of the second surface **32** of the circuit board **30** is positioned to contact the support surface **11B** of the shield member **11** shown in Fig. 1. The through-hole **33** is plated with a conductive material to form plated ground hole **34**, as better shown in Figs. 3-7. The third portion **15** of the ground post **12** extends beyond the ground hole **34**, and the first portion **13** resides within the ground hole **34**.

**[0030]** A second post member **22** is positioned proximate the right-hand side of Fig. 1 and extends in a substantially vertical direction (i.e., downward) from an inner surface **20A** of the second filter housing member **20** toward a terminal end **25** thereof. A recess **26** is formed in the terminal end **25** of the second post member **22**. As shown, preferably

the second post member 22 is substantially coaxial with respect to the ground post 12. The recess 26 is sufficiently dimensioned to receive the third portion 15 of the ground post 12 and to provide a press-fit relationship therewith. That is, it is preferred that the recess 26 of the second post member 22 has an inner diameter that is slightly smaller than the outer dimension of the third portion 15 of the ground post 12.

[0031] In the orientation shown in Figs. 1 and 2B, vertical assembly of the filter housing members 1, 20 involves the application of downward force upon the first surface 31 of the circuit board 30 from the terminal end 25 of the second post member 22. The terminal end 25 of the second post member 22 guides the circuit board 30 downward such that the third portion 15 of the ground post 12 is introduced into the ground hole 34 and seats the second surface 32 of the circuit board 30 on the support surface 11B of the shield member 11. The downward force also causes the third portion 15 to pass through the ground hole 34 and a part of the first portion 13 engages the ground hole 34.

[0032] As shown, for example, in Figs. 2A and 2B, the peripheral shape of the first and third portions 13, 15 of the ground post 12 are polygonal (i.e., square), and the shape of the ground hole 34 is substantially circular. Figs. 2A–2B also show the relationship between the ground post 12 and the second post member 22 and the fit between the first portion 13 of the ground post 12 and the ground hole 34 of the circuit board 30.

[0033] The corner-to-corner dimension of the first portion 13 of the ground post 12 is larger than that of the third portion 15. The outer dimension of the first portion 13 is also slightly larger than the inner diameter of the plated ground hole 34 and can be as large as the inner diameter of the through-hole 33. The outer dimension of the first portion 13 of the ground post 12 can also be slightly larger than the inner diameter of the through-hole

**33** without causing damage to the circuit board **30** upon assembly, as described in more detail below with reference to Fig. 6.

**[0034]** The above-mentioned dimensional relationship between the first portion **13** of the ground post **12** and the ground hole **34** provides a secure electrical connection between the ground post **12** and the circuit board **30** via the plating. That is, the surface structure of the plating is mechanically engaged by the corners of the adjacent polygonal edges of the first portion **13** of the ground post **12** that extends into the plated ground hole **34**.

This relationship provides electrical grounding between the first filter housing member **1** and the circuit board **30** via the ground post **12** without the need to include an additional soldering step, as was heretofore conventionally required, and without peening the tip of the ground post **12**.

**[0035]** The present invention also offers a mechanical advantage over other methods of assembling split filter housings, in that the relationship between the ground post **12** and the second post member **22** provides a secure press-fit that holds the filter housing members **1**, **20** together after vertical assembly is completed. As shown in Fig. 2B, the terminal portion **25** of the second post member **22** is substantially flush against the first surface **31** of the circuit board **30** and circumscribes the ground hole **34**. The third portion **15** of the ground post **12** is securely press-fit within the recess **26** of the second post member **22**. The second surface **32** of the circuit board **30** is substantially flush against the second portion **14** of the ground post **12**. As shown, the terminal end **25** of the second post member **22** is dimensioned to be spaced a distance from the second portion **14** of the ground post **12** by a distance that is substantially equal to the thickness,  $t$ , of the circuit board **30** in order to facilitate the above-described press-fit mechanically

secure relationship upon assembly. Thus, an additional soldering step is avoided and assembly of the first and second filter housing members **1, 20** can be accomplished using Z-axis manufacturing techniques.

**[0036]** Fig. 3 is a cross-sectional view showing a dimensional relationship between the portions of the ground post **12** and the plated ground hole **34** of the circuit board **30** according to another embodiment of the present invention. Fig. 4 is a partial top view of the first surface **31** of the circuit board **30**, the ground post **12** and the plated ground hole **34** shown in Fig. 3. Figs 3 and 4 are best read in conjunction with Fig. 5, which is a cross-sectional view showing the dimensional relationship between the portions of the ground post **12**, the plated ground hole **34** of the circuit board **30**, the terminal portion **25** of the second post member **22** and the recess **26** of the second post member **22**.

**[0037]** As shown in Fig. 3, the ground post **12** includes three portions of varying outer dimensions. The second portion **14** has an outer dimension that is larger than that of the first portion **13**, whose outer dimension is larger than that of the third portion **15**. As mentioned above, it is preferred that at least the first and third portions **13, 15** of the ground post **12** are polygonal in shape, and preferably square, such that the outer dimension is measured as a corner-to-corner diagonal dimension. The second portion **14** can be formed to have any desired peripheral shape, so long as the surface **14A** is sufficient to seat the lower surface **32** of the circuit board **30** upon assembly of the filter housing members **1, 20** shown in Fig. 1.

**[0038]** Small sections of the leading edges **13A** of the first portion **13** are tapered, as are sections of the leading edges **15A** of the third portion **15**. Similarly angled tapered sections are formed on the lowermost portion of the inner peripheral edge **26A** of the

recess 26 of the second post member 22 (see Fig. 5). The tapered sections 15A smoothly guide the third portion 15 of the ground post 12 through the plated ground hole 34 and into the recess 26 of the second post member 22 to provide a press-fit therewith, as described below. The tapered sections 13A guide the first portion 13 into the plated ground hole 34 to engage in the above-described mechanical interference fit with the periphery of the inner diameter thereof.

[0039] The outer dimension of the third portion 15 is slightly smaller than the inner diameter of the plated ground hole 34 such that the third portion 15 will extend therethrough without significant interference and extend a distance beyond the first surface 31 of the circuit board 30.

[0040] As mentioned above, the through-hole 33 is plated with conductive plating from the first surface 31 to the second surface 32 thereof (see Fig. 3) to form the plated ground hole 34. The outer dimension of the first portion 13 of the ground post 12, as shown, is preferably greater than the inner diameter of the plated ground hole 34 but slightly less than the inner diameter of the through-hole 33 itself. This is desired in order to prevent the circuit board 30 from cracking, splitting or otherwise incurring damage when the ground post 12 is inserted therethrough. Although the figures are not drawn exactly to scale, it should be noted that the actual thickness dimension of the plating is on the order of 1 to 10 thousandths of an inch. Thus, precision sizing of the portions of the ground post 12 are preferred according to this embodiment of the present invention.

[0041] While the first portion 13 engages in the above-described mechanical interference fit with the plated ground hole 34, the third portion 15 engages the recess 26 of the second post member 22 in a secure press-fit relationship. That is, the outer dimension of

the third portion 15 is sufficiently larger than the inner diameter of the recess 26, and upon assembly, the vertical force applied by the second post member 22 guides the ground hole 34 of the circuit board 30 over the third portion 15 and further onto the first portion 13 while the third portion 15 is received in the recess 26.

[0042] Tests have shown, however, that properly dimensioning and arranging the through-hole 34 with respect to the circuit board 30 facilitates using a ground post 12 having a first portion 13 whose outer dimension is actually the same size or even slightly larger than the diameter of the through-hole 33 itself without causing any damage to the circuit board 30. This is described in more detail below with reference to Fig. 6.

[0043] Fig. 6 is a partial perspective view showing a preferred distance between the outer peripheral edge of a through-hole 33 and the edges 30A of a circuit board 30. In order for the circuit board 30 to be able to withstand the forces exerted thereon when the outer dimension of first portion 13 of ground post 12 inserted into the plated ground hole 34 is slightly larger than the inner diameter of the through-hole 33 itself, the through-hole 33 should be formed in a portion of the circuit board 30 that will not encourage damage. As shown, the outer peripheral edge of the through-hole 33 should be spaced from the adjacent edges 30A of the circuit board 30 a distance that is at least one-half the thickness dimension,  $t$ , of the circuit board 30.

[0044] Fig. 6 also shows the preferred orientation of the polygonal sides of the post member 12 with respect to the adjacent edges 30A of the circuit board 30. That is, as shown, the flat sides of the first and third portions 13, 15 should run in a direction that is parallel to the adjacent edges 30A of the circuit board 30. This preferred orientation also contributes to the ability of the plated ground hole 34 to best receive the first portion 13

of ground post 12 that has an outer dimension that is slightly larger than the inner diameter of the through-hole 33 itself without damaging the circuit board 30. Rotating the orientation of the sides of the ground post 12 such that they do not run in a parallel direction with respect to the edges 30A of the circuit board 30 introduces the opportunity for stress gradients caused by the ground post 12 corner tips to increase the likelihood of damage to the circuit board 30 upon assembly.

[0045] Fig. 7 is an exploded view of a split filter housing assembly according to another embodiment of the present invention. Like reference numerals have been assigned to like components described above with reference to Figs. 1-6, and additional recitation of previously described features has been omitted.

[0046] The second filter housing member 20 includes a shield member 21 extending radially and vertically (downwardly, as shown) from the inner surface 20A thereof. The shield member 21 is positioned to longitudinally and vertically correspond to the location of the shield member 11 of the first filter housing member 1 and with the position of a receiving slot 35 formed in the circuit board 30. The circuit board 30 includes a pair of opposed through-holes 33 formed on opposite lateral sides of the circuit board 30 and on either side of the slot 35. Each through-hole 33 is plated with conductive plating from the first surface 31 to the opposed second surface 32 of the circuit board 30 to form plated ground holes 34.

[0047] A pair of second post members 22 extend vertically (i.e., downwardly) from the inner surface 20A on opposite lateral sides of the second filter housing member 20 and on either side of the shield member 21. A pair of ground posts 12 extend vertically (i.e., upwardly) from the inner surface 1A on opposite lateral sides of the first filter housing

member 1 on either side of shield member 11. The respective positions of the ground posts 12 and second post members 22 preferably correspond such that, upon assembly, each of the ground posts 12 will be substantially coaxial with a corresponding one of the second post members 22.

[0048] The shield member 11 extending radially and vertically (upward, as shown) from the inner surface 1A of the first filter housing member 1 includes a first surface 11A and an adjacent stepped surface 11B on which a portion 36 of the circuit board 30 sits upon assembly. A third stepped surface adjacent stepped surface 11B can also be provided, as described above with respect to the third stepped portion 11C shown in Fig 1.

[0049] Fig. 7 also shows first and second end caps 40, 41. After the first and second filter housing members 1, 20 are vertically assembled as described above, end cap 40 is positioned proximate the first ends 101, 201 of the assembled filter housing members 1, 20, and the second end cap 41 is positioned proximate the second ends 102, 202 of the assembled filter housing members 1, 20. Thus, the circuit board is captive within the internal cavity created by the abutted first and second filter housing members 1, 20 and closed off by the end caps 40, 41. These end caps 40, 41 can be assembled without the need for solder according to the description included in the above-incorporated '455 and '055 Applications.

[0050] Fig. 8 is a top view of a first filter housing member 1 according to another embodiment of the present invention, and Fig. 9 is an end view of the first filter housing member 1 taken through line 9-9 in Fig. 8. The embodiment of Figs. 8 and 9 differs from the embodiment shown in Fig. 7 in that the first filter housing member 1 includes a pair of shield members 11, 111. The ground posts 12 are positioned on the opposite outer

most sides of the shield members **11**, **111** on opposite lateral sides of the inner surface **1A** of the first filter housing member **1**. Each of the shield members **11**, **111** is provided with a stepped portion **11B**, **111B** on which a portion of a circuit board (not shown) sits upon assembly. Again, the height of the stepped portions **11B**, **111B** should substantially correspond to the height of the second portion **14** of the ground posts **12** to properly support the circuit board **30** within the filter housing assembly.

[0051] Although it is not shown in the drawings, in order to properly fulfill this embodiment of the present invention, a corresponding pair of shield members should be provided on the second filter housing member **20**, and the circuit board should be configured with a slot arrangement sufficient to accommodate the double shields. This type of multiple shield arrangement is described, for example, in the previously herein incorporated '455 and '055 Applications, as well as in U.S. Patent No. 6,429,754, also previously incorporated herein by reference.

[0052] Fig. 10A is a cross-sectional view showing the ground contact formed between the projected edges **133B** of the first portion **133** of the ground post **120** and the plating that forms the ground terminal **342** on the second surface **320** of the circuit board **300** proximate the non-plated through-hole **330** according to another embodiment of the present invention. In addition to the structure of the ground post **12** shown in Fig. 3 and described above, the first portion **133** of the ground post **120** includes a plurality of projecting edges **133B** extending outwardly toward the surface **144A** of the second portion **144**. Unlike the tapered sections **133A** and **155A**, which function much in the same way as the tapered sections **13A** and **15A** described above with reference to Figs. 3

and 5, the projected edges **133B** do not extend from the entire outer periphery of the first portion **133**.

[0053] As shown in Fig. 11A, the projected edges **133B** are relatively sharply angled, fin-like extensions of the corner portions of the polygonal (i.e., square) first portion **133**.

Upon assembly, the projected edges **133B** engage and indent the planar surface of the ground terminal **342** on the second surface **320** of the circuit board **300** in the vicinity of the non-plated through-hole **330**. In that manner, and as shown in Fig. 10A, secure ground contact between the first filter housing member **1** and the circuit board **300** is achieved in a solderless manner. The manner in which the solderless ground contact is achieved is different from the solderless manner in which the ground post **12** interacts with the plated ground hole **34** in the embodiments shown in Figs. 1-9, however, in that this embodiment affords additional benefits by providing ground terminals on both surfaces **310** and **320** of a circuit board **300** rather than employing a plated ground hole.

[0054] That is, since the through-hole **330** itself is not through-plated with a conductive material, the expense associated with various methods for evacuating excess solder accumulated in plated ground holes during wave soldering steps involved in the fabrication of the circuit board itself are eliminated. Thus, the present invention offers reduced production cost and increased manufacturing efficiency by eliminating these additional steps.

[0055] Fig. 10B is a cross-sectional view of the structure of Fig. 10A shown rotated about 45° with respect to the substantially coaxial central axes of the ground post **120** and the second post member **220**. In addition to the structure of the second post member **22** described above and shown in Figs. 1 and 5, for example, the terminal end **225** of the

second post member **220** includes a planar portion and a plurality of projected portions **227** extending downwardly and slightly outwardly therefrom. As shown in Fig. 10B, the projected portions **227** are formed in a substantially pyramidal shape, wherein a first side face of the pyramid is defined by an extension of the angled lowermost portion of the inner peripheral edge **226A** of the recess **226**, the base of the pyramid is defined by the planar portion of the terminal end **225**, and the other two faces are angled surfaces extending from and beyond the planar surface of the terminal end **225** which join with the first side face in a point.

[0056] Fig. 11B is a partial bottom view of the second post member **220** and the circuit board **300**, shown rotated approximately 45° about the central axis of the second post member **200** and with respect to the view shown in Fig. 11A. As shown, the projected portions **227** are relatively sharply angled members extending from the terminal end **225** of the second post member **220**. Upon assembly, the projected portions **227** contact, engage and indent the planar surface of the ground terminal **341** on the first surface **320** of the circuit board **300** in the vicinity of the non-plated through-hole **330**. In that manner, and as shown in Fig. 10B, secure ground contact between the second filter housing member **20**, the circuit board **300** and the ground post **120** is achieved in a solderless manner.

[0057] In Figs. 10A and 10B, the dimensions of the portions of the ground post **120** correspond to the dimensions of the through-hole **330** and the recess **226** formed in the second post member **220** in substantially the same manner as described above with reference to Fig. 5. The polygonal edges **133B** of the first portion **133** of the ground post **120**, however, extend outwardly toward the second portion **144** as described above. Also,

as shown in the rotated view of Fig. 10B, the projected portions **227** extend downwardly and slightly outwardly from the terminal end **225** of the second post member **220**, as described above.

[0058] As shown in Fig. 10A, the ground connection between the circuit board **300** and the first filter housing member **1** (see, for example, Fig. 7) from which the ground post **120** extends, is achieved, in part, via the interference fit between the projected edges **133B** of the first portion **133** of the ground post **120** that contact, engage and indent the planar surface of the ground terminal **342** formed on the second surface **320** of the circuit board **300**. Mechanical engagement between the second surface of the circuit board **300** and the projected edges **133B** of the ground post **120** is also provided.

[0059] As shown in Fig. 10B, a ground connection between the circuit board **300** (the ground terminal **341** on the first surface thereof), the second filter housing member **20** and the ground post **120** is also achieved, in part, via the interference between the projected portions **227** of terminal end **225** of the second post member **220** that contact, engage and indent the planar surface of the ground terminal **341** formed on the first surface **310** of the circuit board **300**. In that manner, and by virtue of the secure press-fit relationship between the third portion **155** of the ground post **120** within the recess **226** of the second post member **220** upon assembly, the two ground terminals **341**, **342** are effectively unitized into a single ground terminal to provide a substantially similar ground potential for the circuit board **300** and the filter housing members **1**, **20**.

[0060] It should be noted that the position of the projected portions **227** about the periphery of the second post member **220** should be off-set from the position of the projected edges **133B** of the ground post **120** by about 45°, with respect to the

substantially coaxial central axes of the ground post **120** and the second post member **220**. That is, if the positions of the projected portions **227** correspond to the positions of the projected edges **133B** on opposite sides of the circuit board **300**, it will be difficult to achieve the structural relationship shown in Figs. 10A and 10B because the opposed projected portions **227** and projected edges **133B** will effectively abut and pinch either side of the circuit board only in those abutted positions, which does not adequately provide the desired mechanical engagement with the circuit board **300**. If, on the other hand, the projected edges **133B** and the projected portions **227** are offset from one another by about 45°, for example, the circuit board **300** will effectively be crimped between the off-set opposing projected edges **133B** and projected portions **227** in more locations about the periphery of the through hole **330** to provide better mechanical engagement and electrical contact.

[0061] Like the embodiment shown in Fig. 5, the embodiment shown in Figs. 10A and 10B offers a mechanical advantage over other methods of assembling split filter housings, in that the relationship between the ground post **120** and the second post member **220** provides a secure press-fit that holds the filter housing members **1, 20** together after vertical assembly is completed. Similar to the embodiment shown in Fig. 2B, during assembly, the planar portions of the terminal end **225** of the second post member **220** are positioned to be substantially flush against at least a portion of the first surface **310** (including portions of the plating **341** formed thereon proximate the through-hole **330**) of the circuit board **300** such that the terminal end **225** of the second post member substantially circumscribes the through-hole **330**. As mentioned above, however, the protruded portions **227** of the terminal end **225** of the second post member

**220** are not flush against the plating **341**, but instead engage and indent the planar surface of the plating **341** at those positions to provide sufficient electrical contact and an additional mechanical engagement with the first surface **310** of the circuit board **300**, as well. The third portion **155** of the ground post **120** is securely press-fit within the recess **226** of the second post member **220**, and portions of the second surface **320** of the circuit board **300** are positioned to be substantially flush against the second portion **144A** of the ground post **120**. As shown, the planar portion of the terminal end **225** of the second post member **220** is dimensioned to be spaced a distance from the second portion **144A** of the ground post **120** by a distance that is substantially equal to the combined thickness,  $t'$ , of the circuit board **300** and the thickness dimensions of the plating **341**, **342**, in order to facilitate the above-described mechanically secure press-fit relationship upon assembly.

[0062] It should also be noted, however, that while it is preferred to provide the projected portions **227** on the terminal end **225** of the second post member **220** as described above to provide additional structural stability (mechanical engagement) and ensure that the filter housing members **1**, **20**, the ground post **120**, the second post member **220** and the circuit board **300** are at substantially the same ground potential, a good ground connection and secure press-fit relationship can be achieved even without the projected portions **227**. In that case, while the terminal end **225** of the second post member **220** would not substantially indent the planar surface of the ground terminal **341** on the first surface **310** of the circuit board **300**, the ground connection is achieved by the secure press-fit contact relationship between the ground post **120** within the recess **226** of the second post member and the contact relationship with the ground terminals **342**, **341** on the circuit board **300** interposed therebetween.

**[0063]** As mentioned above, by providing a non-through plated through-hole in the circuit board, the expense associated with additional steps to remove solder accumulated in a plated ground hole are eliminated. Furthermore, an additional soldering step is avoided and assembly of the first and second filter housing members **1**, **20** can be accomplished using Z-axis manufacturing techniques.

**[0064]** While the present invention has been particularly shown and described with reference to the preferred mode as illustrated in the drawings, it will be understood by one skilled in the art that various changes in detail may be effected therein without departing from the spirit and scope of the invention as defined by the claims.